Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

It is approved
on meeting of department of
medical informatics, medical and biological physics
27 August 2020
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Head of department ________O.V.Silkova

Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	1. Fundamentals of higher mathematics and biological physics
Theme of lecture:	**Fundamentals of materials engineering in dentistry. Determination of the density of dental materials.**
Year	1
Faculty	Stomatological
Speciality	Stomatology

Poltava - 2020

The topic significance:

The meaning of various tissues density and environments of the body, for example, muscular, cartilage, lymphatic, blood and of other tissues, and also wet, has in medicine the large practical importance.

In stomatological practice it is important to practice to know the density of dental materials and the density of tooth substance, that depends significantly on the age of a man and his diseases.

Specific targets:

To have general knowledge of the topic studied;
To understand, to remember and to use the knowledge received;
To know definition of density and methods of its measurement;
To learn to determine density of dentist materials (basic and sealing up materials, crown, teeth) with the help of hydrostatic weighing;
To be able to carry out laboratory and experimental work.

Materials for the before – class work self – preparation work:

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects:

Science	To know	To be able to
basis knowledge of: physics chemistry	the concept of density; connection of phycal and chemical structure and properties of substances	to measure the density of bodies of the correct and wrong geometrical forms

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
density	Mass in unit of volume.
crystal lattice	geometrically regular structures, which is formed by atoms or molecules al located in strict arrangement; they lie in nodes of *lattice*
Liquid crystal	substance with properties both liquid and crystal: it flow as liquid, but have optical properties of crystals. Molecules are ordered in material.

***Theoretical questions to be answered*:**

1. The density of the body.
2. The law of Archimedes.
3. Methods of the density measurement of the body with wrong geometrical form.
4. The method of hydrostatic weighing for definition of density of bodies of the wrong geometrical form.

The practical work executed in class: To learn the method of hydrostatic weighing for the measurement of the tooth density and of the dental materials.

Take the possession of the method of hydrostatic weighing for the measurement of a tooth density and of the dental materials.

Torsion balance (torsion scales) are intended for weighing of small loads at maintenance of sufficient precision (a maximum load of 500 mg precision of weighing of 1 mg).

Basic element of torsion scales is the spiral spring, which twists under activity of a weighed subject. The principle of this device consists in the following (fig. 1, B).

Torsion scale must be positioned before work with using of level gauge 2 and adjusting screws 3.

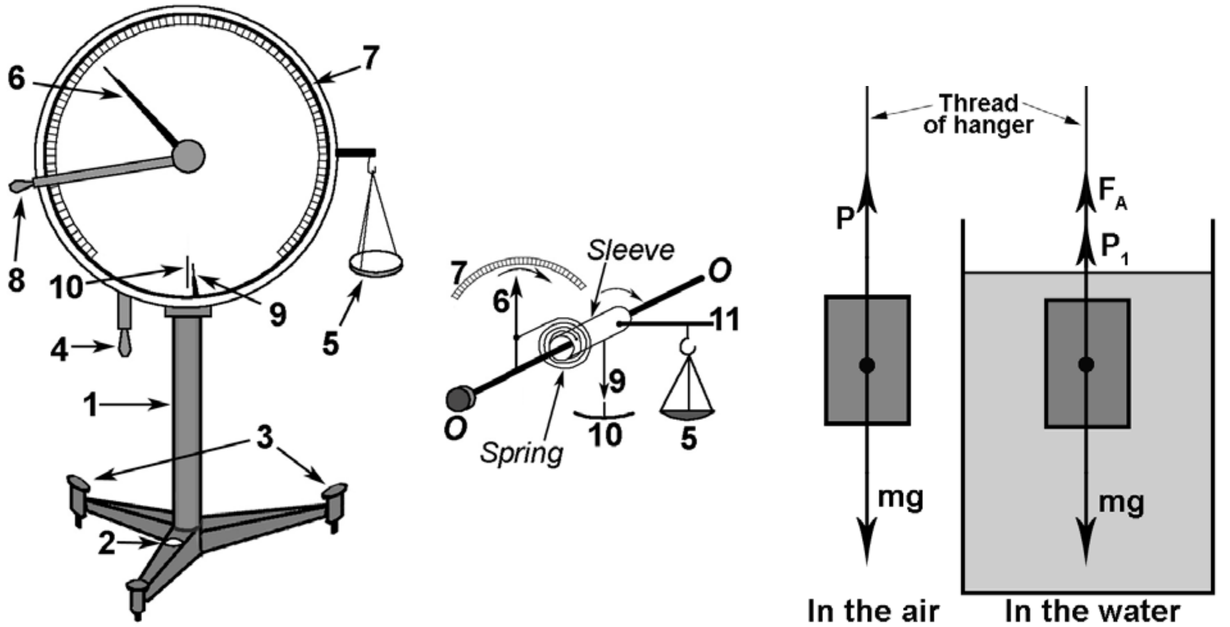
Arrest is part of device that stop its mechanism for the purpose of protect against damage during movement. Arrestment of scale is realized by handle 4. It must be in position “Closed” during relocation of device and during weight loading and unloading.

Sleeve is joined with ***arms of a balance*** 11 [balance-beam, scale-beam, weighbeam] suspended to it the pan 5 for weighed loads and a balance indicator 9. Sleeve is sticked on of central axis in the hull with a dial 7 [scale of weights].

One end of a spiral spring is joined to sleeve. Sleeve with arms of a balance has an opportunity freely to rotate around of axis OO. On the same axis the weight index 6 with handle 8 rigidly hardened. The other end of spiral spring is attached to weight index.

Without loading the weight index 9 should sets on zero division of the dial, and the balance indicator 9 should be overlapped with the line 10 scoring an equilibrium. At a loading equilibrium is broken, the pan of weights sinks and, turning thus sleeve, twists spring. For scale rebalancing, it is necessary to turn the weight index 6 aside, opposite to rotational displacement of arms of a balance under activity of a load. Quantity of required rotational displacement of the index 6 is equal to an amount of twist of a spiral spring and proportional to twisting effort, that is, proportional to a weight of a body.

Travel of the index 6 is digitized on scale 7 graded in milligrams.



A **B** **C**

***Fig.1. Torsion scales: A) overview; B) scale's mechanism; C) method of weighting*.**

Suspend a tooth on a string to the beam of the scales;
- determine its weight in the air *P*;
- determine its weight in the distilled water P_1;
- calculate the density of a tooth under the formula $c = \frac{P c_0}{P - P_1}$;
- make the similar measurements for an alloy and basic plastic;
- put the results into the table.

Result table

Material	Weight in air, N	Weight in water, N	Buoyant (expulsive) force, N	Water density, kg/m^3	Material under consideration density, kg/m^3
Tooth					
Alloy					
Basic plastic					

- Make conclusions.

Content of the topic

Material structure

Every two neighbour atoms or molecules interact at small distance. Two kind of forces are – attractive and repulsive. Attraction forces grows with approaching less than repulsion forces (fig.2), but grow down with distance less too. As result, the so-called "potential well" is formed. On fig.2. it is position B – maximum of attraction forces.

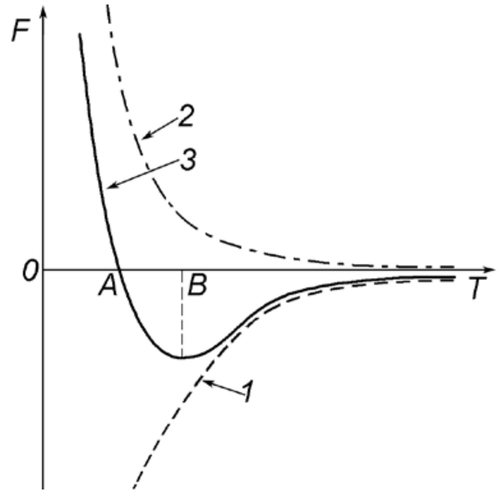
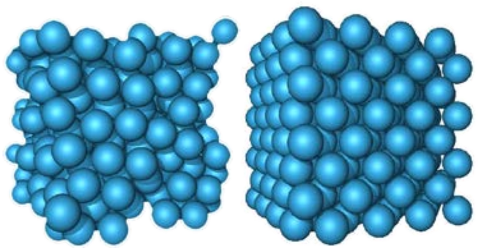


Fig.2. Forces of interaction between atoms in matter.
1 – attraction forces, 2 – repulsion forces, 3 – resultant curve.
A – equilibrium position,
B – position of attraction maximum.

If energy of inter-molecular interaction in ideal gas is many times less than average energy of chaotic thermal movement, then in crystal – conversely. Therefore thermal movement can not destroy bonds between particles. Energy of thermal movement determines amplitudes of molecules deviation from equilibrium distance 0A, and correspondingly – aggregative state, density, viscosity of liquids and gases, hardness and elasticity of solid bodies and so on.

Solid material can be crystalline or amorphous.

Crystal is a substance, in which atoms or molecules are located in strict arrangement; they lie in nodes of geometrically regular structures and they form *crystal lattice* [*crystal matrix*]. Lattice – synonym grating. Character of a crystal state is *anisotropy* [directional property]: it is dependence of physical properties (mechanical, optical, electrical, and thermal) on direction.



A B

Fig.2. Liquid (A) and solid (B) bodies.

Crystal lattices can be ionic, atomic, metallic and molecular in dependence on kinds of crystal particles and interaction forces between them.

Ionic crystal lattice is built by ions of opposite charges. Interaction forces are Coulomb's electrical forces. Whole crystal is similar to one molecule. Sample is crystal lattice of NaCl (fig.3,a).

In ***atomic crystal*** all particles are neutral atoms with covalent bonds between them. Covalent bonds are provided with collectivized electrons. They are very steady. The examples are crystals of diamond, silicon, germanium, CuCl. Such lattices are represented in fig.3,b and c.

In ***metal crystals*** electrons of external layers (valence electrons) are connected with atom nucleus very weakly. They leave atom easyly and can skip to external orbits of other atom electron shell. These electrons behave as free electrons and form the so-called “electron gas”. They provide conductivity of metal and have name “conduction electrons”. Atoms lost electons get positive charge, and free place in shell is the so-called “hole”.

Thus, in *lattice points* [*nodes*] of metal crystal positive metal ions are located; electrons chaotic move between them. Such bonds kind (ions and electrons system) is called as metal bond.

Such crystals are clear metals. Typical crystal lattice is cube or hexagonal prism with density packing of atoms.

Molecular crystal is formed by molecules with certain orientation. Between them inter-molecular interactions are. Bonds are polar covalent bonds. The examples are ice and sulfur.

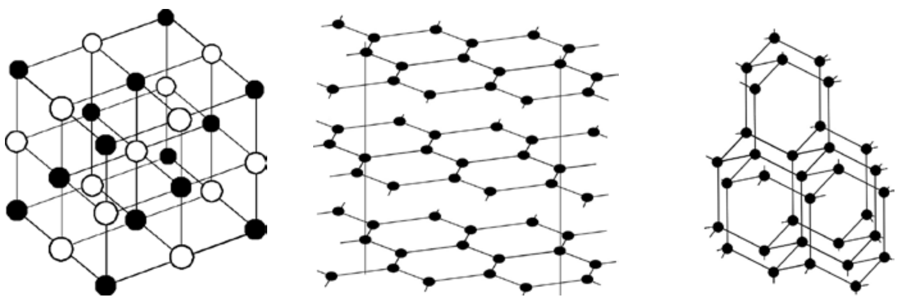
Amorphous bodies are characterizes by presence of nearby order and absence of distant order. It means that adjacent particles have some order of mutual location, but with distance this order disturbs. It is result of larger intrinsic energy than in crystal. Amorphous bodies are in equilibrium state usually at relatively high temperature and low pressure.

They are similar to supercooled liquids with very high viscosity coefficient. At grows of pressure and decrease of temperature amorphous bodies will stay solid (so-called ***glassy state*** or *vitrescence*), in opposite case – stay liquid (low-molecular substances) or high-elastic (intermediate state between liquid and solid).

Amorphous bodies can be fluid, elastic or fragile in depend on outer influence characteristics: pressure and rate of influence. For example, piece of pitch [resin, gum], which seems a hard, can crack at sharp strike, and can flow, spread if it lies under load (for example, gravitation) long time. The examples are amber, glass, rosins and many polimers.

Polymers are substances in which molecules are long chains and consist of many atoms linked by chemical bonds. They can be liquid or solid (crystal or amorphous) but not gas. Most of materials of live and plant origin (cotton, wool, skin, hair, horn, natural caoutchouc) and main part of synthetic material (plastics, fibers, resin) are polymers.

Mechanical properties of polymers are specific: high durability at high elasticity (ability to great reversible deformation). Many polymers are convenient for fiber



a **b** **c**

Fig.3. Crystal lattices: (a) NaCl type – cubic lattice; (b) graphite – planes with hexagonal cells; (c) diamond – tetrahedral structure.
White balls mark one type of ions, black balls mark others.

production. They can have dielectric properties.

Macromolecule of polymer is flexible. Change of positional relationship of macromolecule parts call as conformational alteration.

Amorphous polymer in high-elastic state is able to extremely strong reversible deformation (some – up to 1000%). It is result of conformational ability. If polymer molecules usually are bent, under stretching loading they are straightened along load direction – length of body extends. After release molecules forms restore as result of chaotic thermal movement – length of body restores.

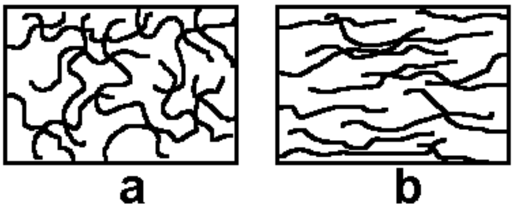


Fig.4. Polymer molecules forms in free state (a) and under loading (b).

Times of deformation and restoration in polymers are greater than in metals.

Deformation of polymers is called viscoelastic, as viscous flow and high elasticity are combined in it.

Polymers are used for construction of medicine instruments; prosthetic devices of blood vessels, heart valves, eye lenses, other elastic organs; for membranes of artificial kidney (plasmapheresis – artificial blood purification as result of partial penetration plasma substances through membrane); for tissues adhesives.

Liquid crystals are substances with properties both liquid and crystal. They flow as liquid, but have optical properties of crystals. There are three kinds of liquid crystals: *nematics*, *smectics* and *cholesteric* liquid crystals. Molecules of liquid crystals have prolate, stretched shape in the form of rod or elongated plate. As result, molecules can be ordered in material by different ways (fig.5).

In nematics their molecules oriented parallelly, but their centers are located disorderly (fig.5, a). In smectics molecules are allocated in parallel layers; in these layers molecules are more or less ordered. Long axes of molecules are perpendicular to layer planes (fig.5, b). In crystals of cholesterics molecules are allocated in parallel layers too; but in every layers molecules are oriented in layer plane as in nematics; long axis's of molecules lie in layer plane. From one layer to other layer orientation of molecules axes rotate at small angle (fig.5, c) – spiral twisting of molecular structure has place. Rotation angle usually is near to 15º.

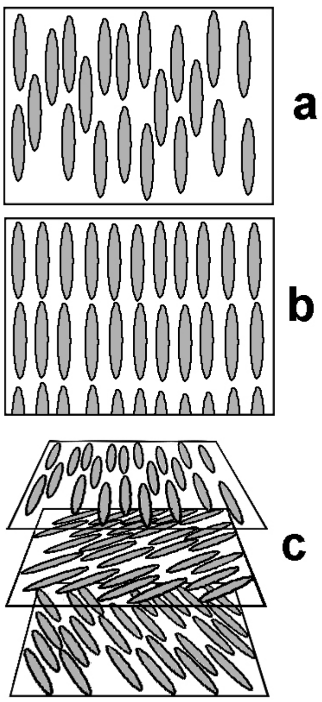


Fig.5. Allocation of molecules in nematics (a), smectics (b) and cholesteric (c) liquid crystals.

Molecular structure of cholesteric liquid crystals is very sensible to easy outer influence as intermolecular forces are weak. Such structure change can carry to change of optic properties (color, polarization, transparency). Color of many cholesterics depend on temperature and can change from violet to red. They are used for temperature measuring, temperature signal sensor. Color of some cholesterics change in the presence of very low concentration of specific chemical substances vapour. They are used as sensor of these substances traces. Electric field change transparency of cholesterics – it is used in clock-face and in other two-color digital indicators.

Exact structure of solid body depend on not only the atomic composition, but on the history of body formation. So, carbon can has three solid structures: diamond, stone coal (anthracite), and graphite with different lattices and physical properties.

The density is the weight of the substance located in the volume unit of the body. It is one of the physical characteristics of the substance and it is determined under the formula:

$$\rho = m/V,$$

where ρ – density, m – weight of the body, V – its volume.

For determining the weight of the body with a wrong geometrical form, for example, a tooth crown or dental materials, it is necessary to carry out the hydrostatic weighing, which is based on the law of Archimedes. According to this law, on the body, shipped in a liquid, the pushing out force works which is directed upwards and is equal to the weight of the liquid volume of the shipped body.

To determine, for example, the density of a tooth, it is necessary to adhere it for a string of the beam of the torsion scales and to determine of its weight in the air (P). Then to ship a tooth in distilled water and to determine its weight in the water (P_1).

The size of the pushing out force F will be equaled:

$$F = P - P_1,$$

where P - weight of a tooth in the air, P_1 - weight of a tooth in the water.

By substituting the meaning of the pushing out force:

$$F = \rho_0 V g,$$

where ρ_0 – density of water, V – volume of a tooth substance, g – acceleration of a free falling in the previous equation the volume can be determined:

$$V = F/\rho_0 g = (P - P_1)/\rho_0 g, \quad (1)$$

The weight of a tooth we find by the size of its weight in the air:

$$m = P/g, \quad (2)$$

Knowing the volume of a tooth and the weight, it is possible to determine its density on the equation:

$$c = \frac{m}{V} = \frac{P}{g} : \frac{P - P_1}{c_0 g} = \frac{P c_0}{P - P_1}, \quad (3)$$

The note: During weighing in the water it is necessary to watch, that the tooth should not touch the walls of the vessel and that there were no bubbles of the air on it. At presence of bubbles of the air it needs to be got out of the water and again slowly shipped back.

Self-control material

A. Test tasks to be done:

1. What does "density of a tooth" mean:
   a) density of enamel;
   b) density of dentine;
   c) density of cement;
   d) average density of the specified parameters.
2. A body, which density is more, than the density of the liquid floats in this liquid. It means, that:
   a) the body has an aperture;
   b) the body has emptiness;
   c) the body has the spherical form;
   d) the body has the cubic form.

B. Test tasks to solve:

1. The part of a tooth crown has mass of 147 mg and under water weight 1,3 mN. Whether It is possible to affirm, that it contains gold? The density gold-loaded alloys is within 14–18 g/cm^3.
2. The bridge prosthesis made of the titanium has 9 g mass. Whether it contains hollows if it has the under water weight 9 g-force? Density of the titanium is 4,5 g/cm^3.
3. The part of a bridge prosthesis has the mass of 450 mg and the under water weight 350 mg-force. Whether It is possible to affirm, that it is made of the titanium? Density of the titanium is 4,5 g/cm^3.
5. The base of a prosthesis made from plastic has mass of 56,5 g. Whether it contains hollows if it has under water weight 2,5 g-forces? Density of plastic is within 1,1–1,2 g/cm^3.

Literature recommended

Main sources.

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